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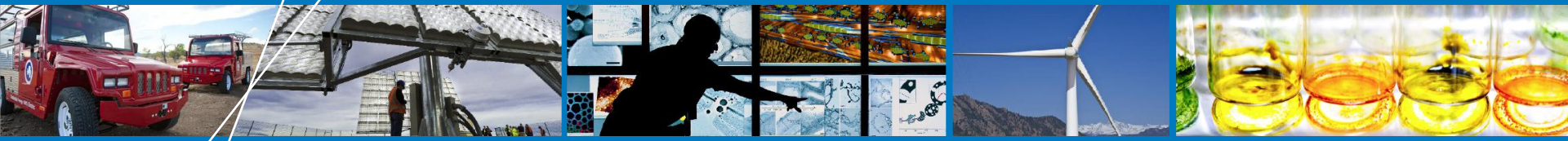
SAM PV Performance Model Validation



SAM Webinar

Janine Freeman

December 11, 2013

Results Sneak Peak

FOR THIS VALIDATION STUDY

- **Identified two known causes of error:**
  - Snow cover
  - Backtracking implementation error in SAM
- **Annual agreement within ± 3%**
- **Hourly agreement:**
  - RMSE within 5.1%
  - MBE within ± 1.0%
- **Seasonal variation in monthly error**
- **No increase in error with increase in system size**

SAM Webinar Schedule for 2014

System Advisor Model

Schedule

- **New Features in SAM 2013 and Beyond**
  - October 9, 2013: Paul Gilman
- **SAM PV Model Validation using Measured Performance Data**
  - December 11, 2013: Janine Freeman
- **Solar Resource Data 101**
  - February 12, 2014: Janine Freeman
- **Analysis of Electricity Rate Structures for Residential and Commercial Projects**
  - April 16, 2014: Sean Ong
- **Modeling Parabolic Trough Systems**
  - June 18, 2014: Michael Wagner

Details

- All sessions last one hour and begin at 1 p.m. Mountain Time
- You must register to participate
- Registration is free, but space is limited
- More details and registration information on Learning page of SAM website

https://sam.nrel.gov/content/resources-learning-sam

Webinar Outline

- Introduction to Validation Project
- Methodology
- Known Causes of Error
- Validation Results
- Conclusions and Future Work
- Questions

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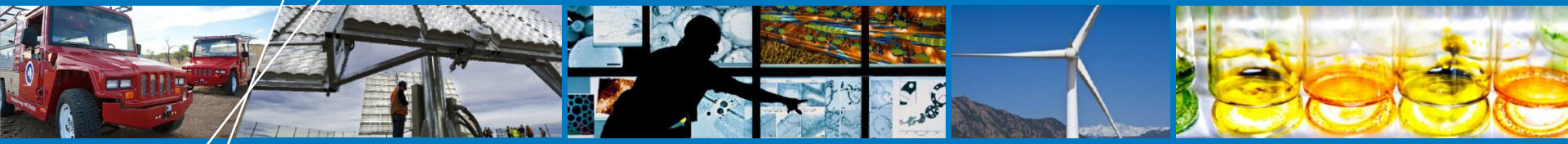


Introduction to the Validation Project

Models Available in SAM

Performance Models

- Photovoltaic Systems
- Concentrating Solar Power
  - Parabolic Trough
  - Power Tower
  - Dish-Stirling
- Solar Water Heating
- Wind Power
- Geothermal Power
- Biomass Power

Key outputs

- Hourly energy production (kWh)
- Capacity factor

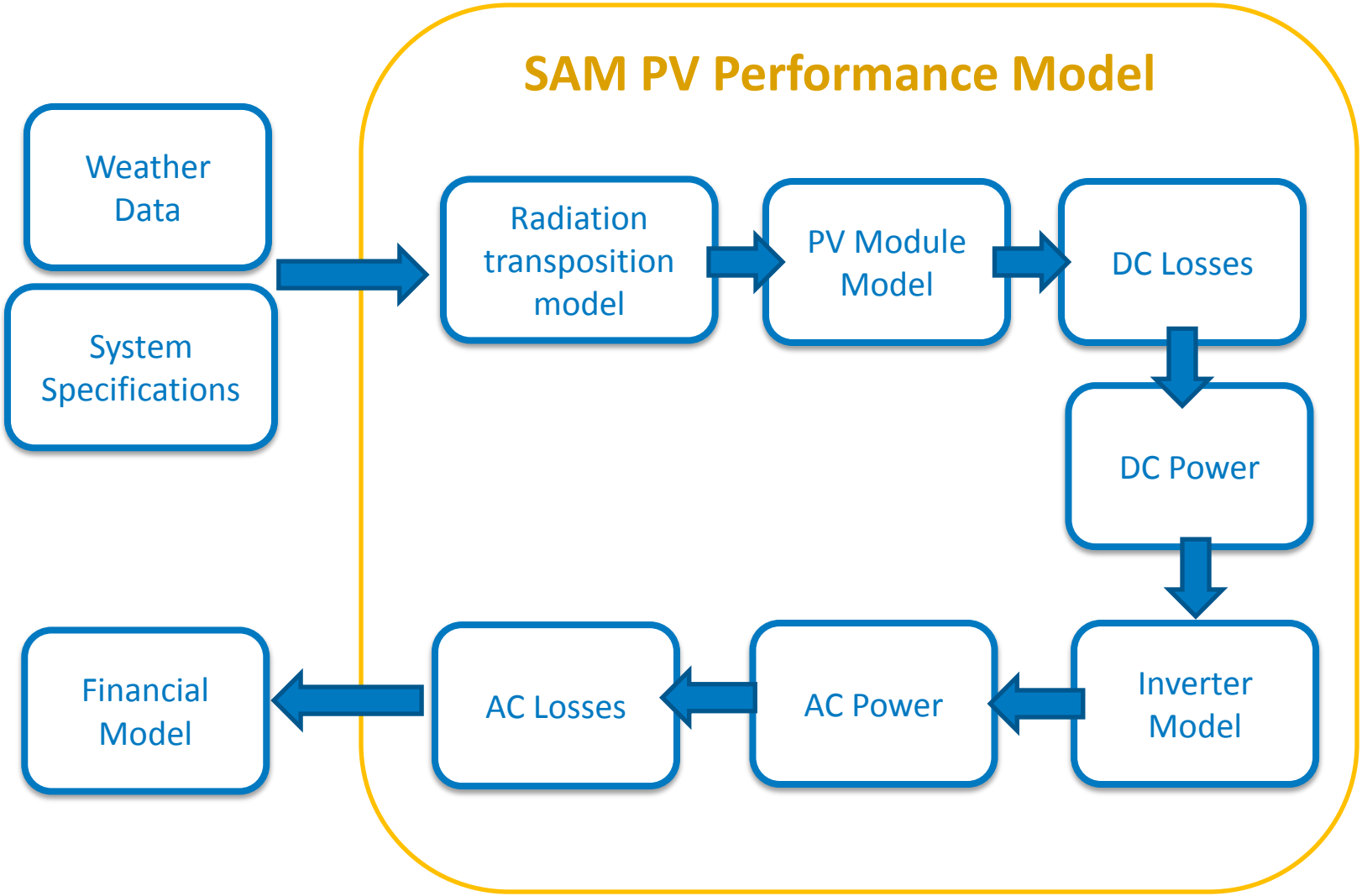
Financial Models

- Residential, commercial, or utility scale
- Installation and operating costs
- Tax credit and payment incentives
- Complex electric utility rates

Key outputs

- Levelized Cost of Electricity (LCOE)
- Payback
- Net present value
- Multi-year cash flow

SAM PV Model Overview



Why Validate the Performance Model?

System Advisor Model

- Compare the PV model to measured data
- Identify areas for improvement or model development
- Provide information to increase confidence in PV modeling, which translates to reduced investment risk for the industry

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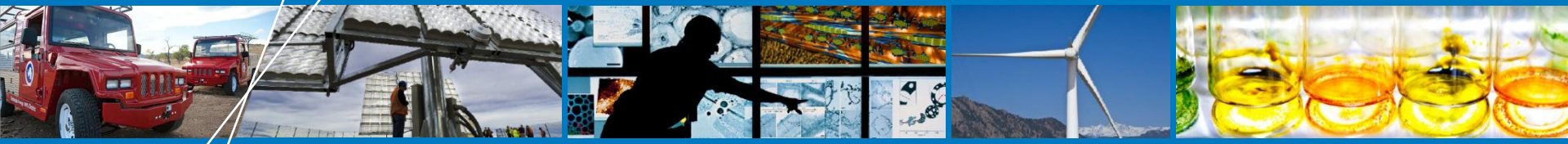


Methodology

Systems Studied

- **9 systems:**
  - 7 fixed tilt, 2 one-axis tracking
  - Washington DC, Golden CO, Arcadia FL, and the Southwestern US
  - 6 commercial-scale, 3 utility-scale

System	Size	Location	System Type
DOE Forrestal	205 kW	Washington, D.C.	Fixed tilt
NREL S&TF	75 kW	Golden, CO	Fixed tilt
NREL RSF1	385 kW	Golden, CO	Fixed tilt
NREL RSF 2	408 kW	Golden, CO	Fixed tilt
NREL Visitor Parking	524 kW	Golden, CO	Fixed tilt
NREL Mesa Top	658 kW	Golden, CO	One-axis tracking
FirstSolar2	Utility	SW USA	Fixed tilt
DeSoto	25 MW	Arcadia, FL	One-axis tracking
FirstSolar1	Utility	SW USA	Fixed tilt

Data Collection

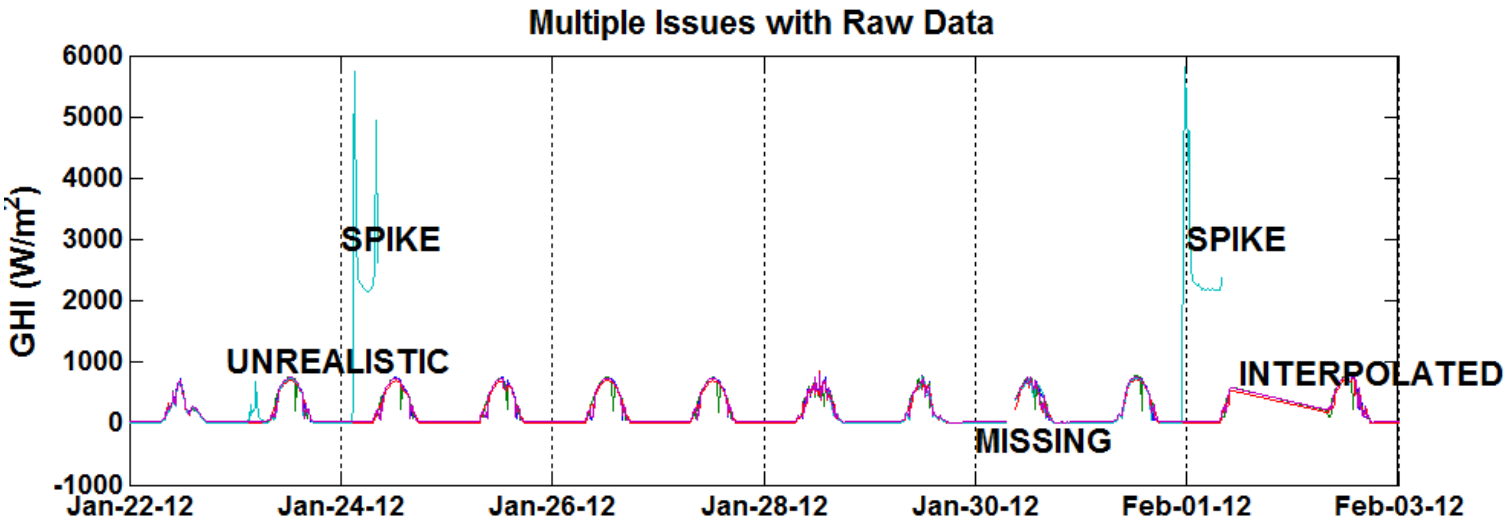
- Measured performance data and system specifications provided by owner/ operator
- Concurrent measured or satellite-modeled weather data (versus TMY)

Necessary Specifications

- System size
- Module
- Inverter
- Modules per string
- Strings in parallel
- Tilt angle
- Azimuth angle
- Fixed or tracking

Challenges of Using Measured Data

- Nighttime hours removed
- Data quality control performed



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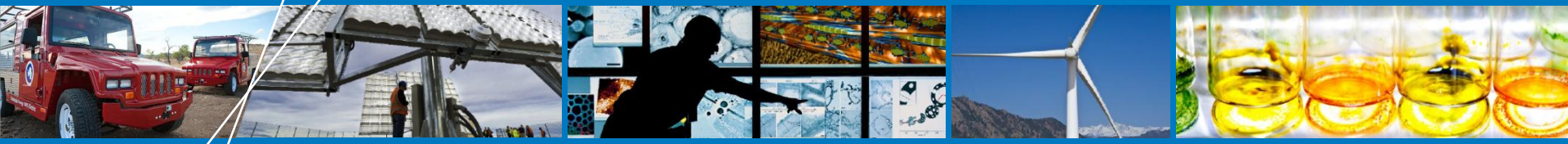
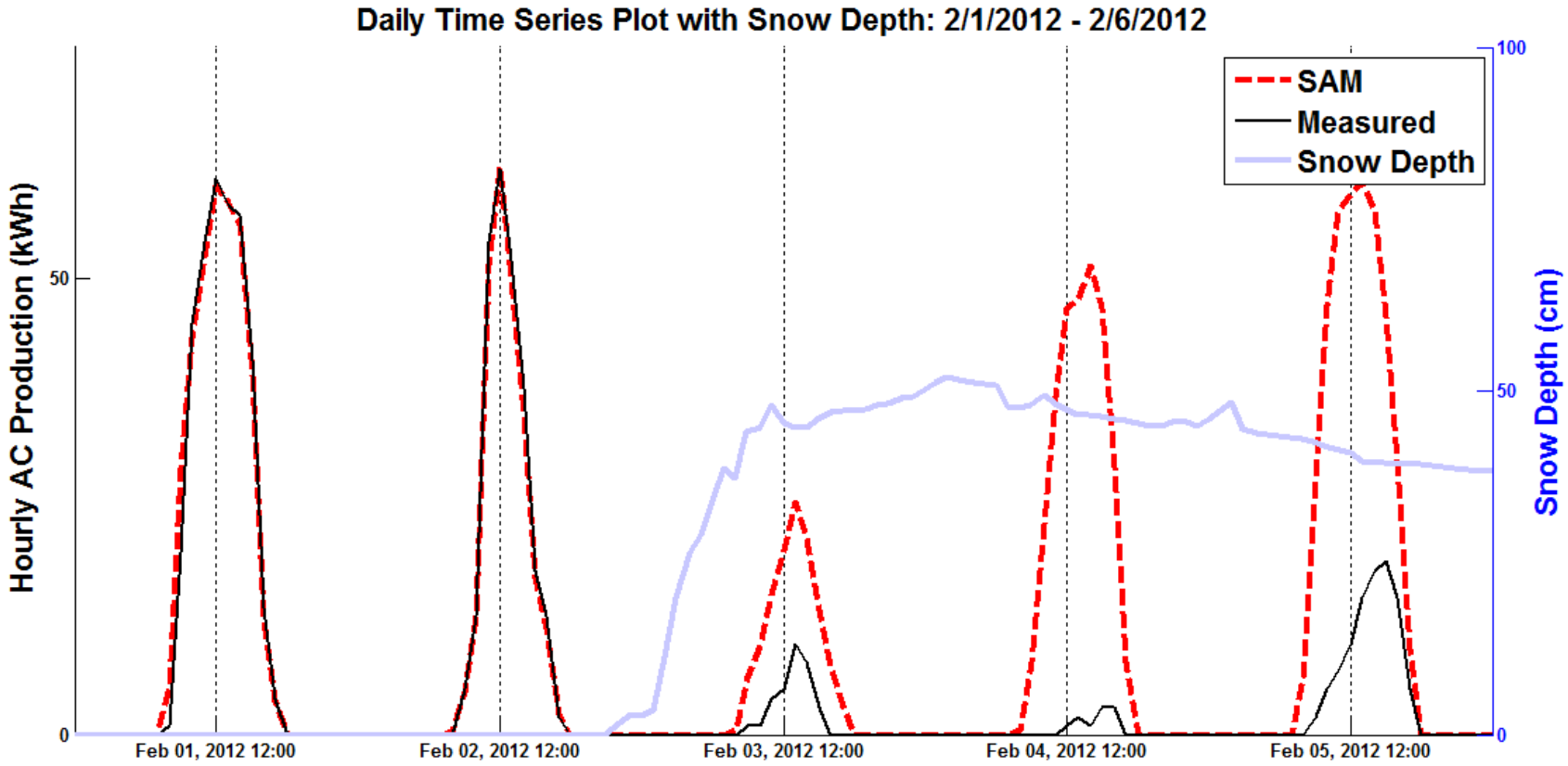


Known Causes of Error

The Significant Effects of Snow Cover

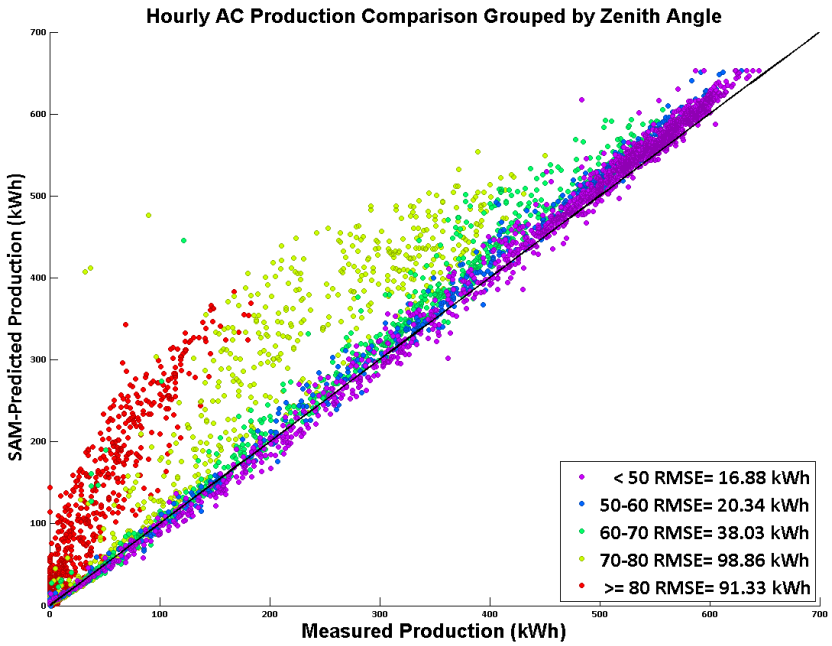
System Advisor Model



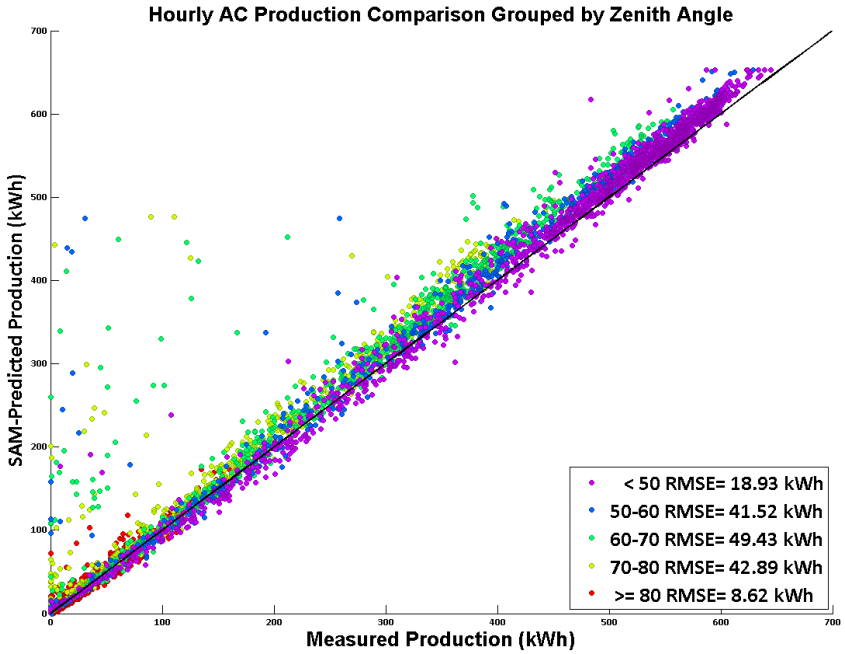
RSF1 System (Golden, CO)

Resolved Backtracking Error

SAM 2013.1.15



SAM 2013.9.20



Mesatop One-Axis Tracking System (Golden, CO)

Hours experiencing snow cover excluded

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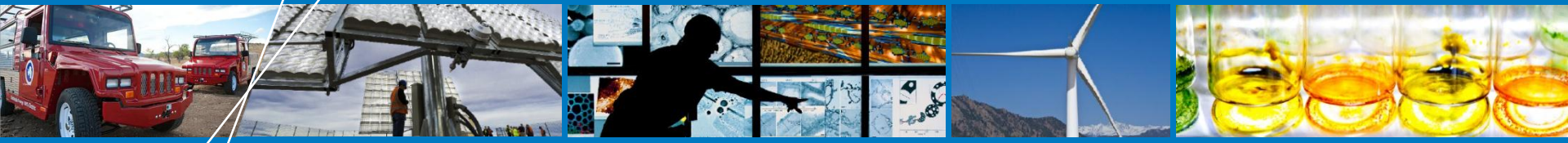
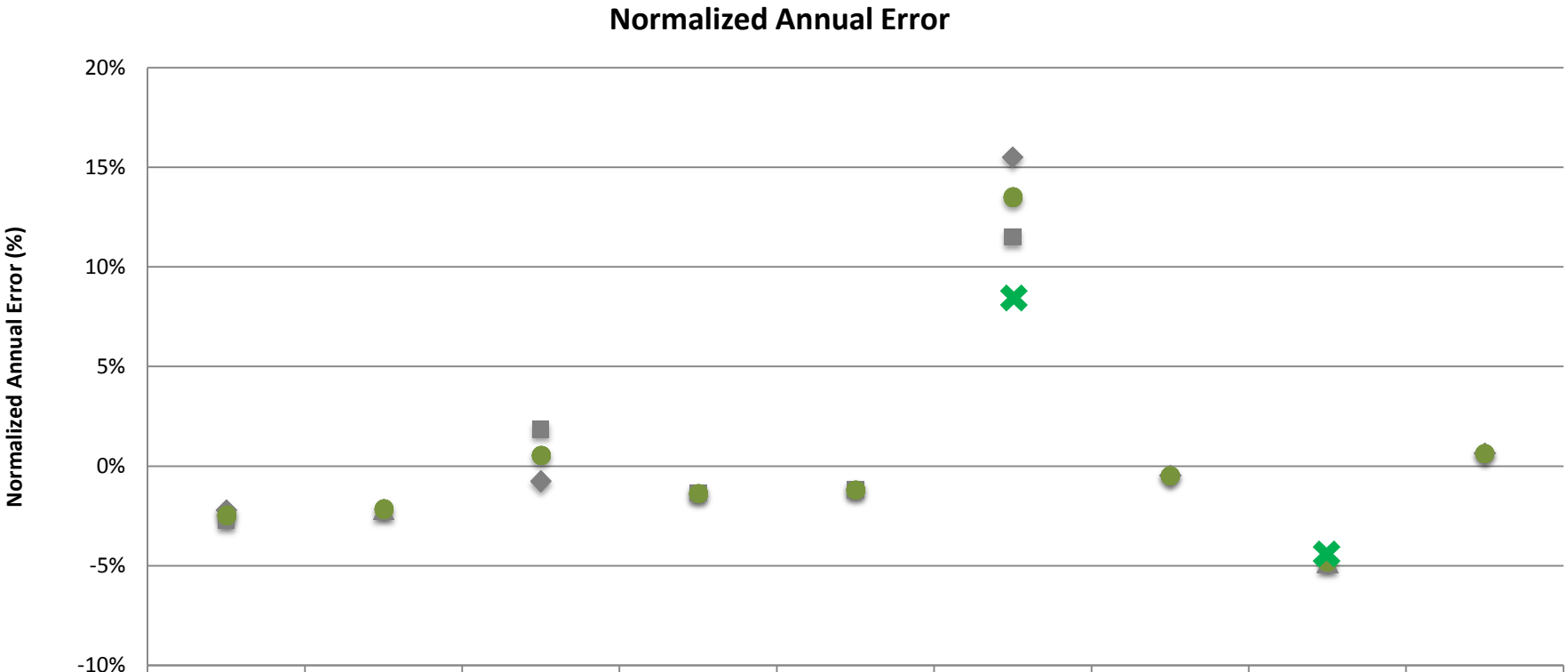


Validation Results

Annual Error In Order of Increasing Size

System Advisor Model

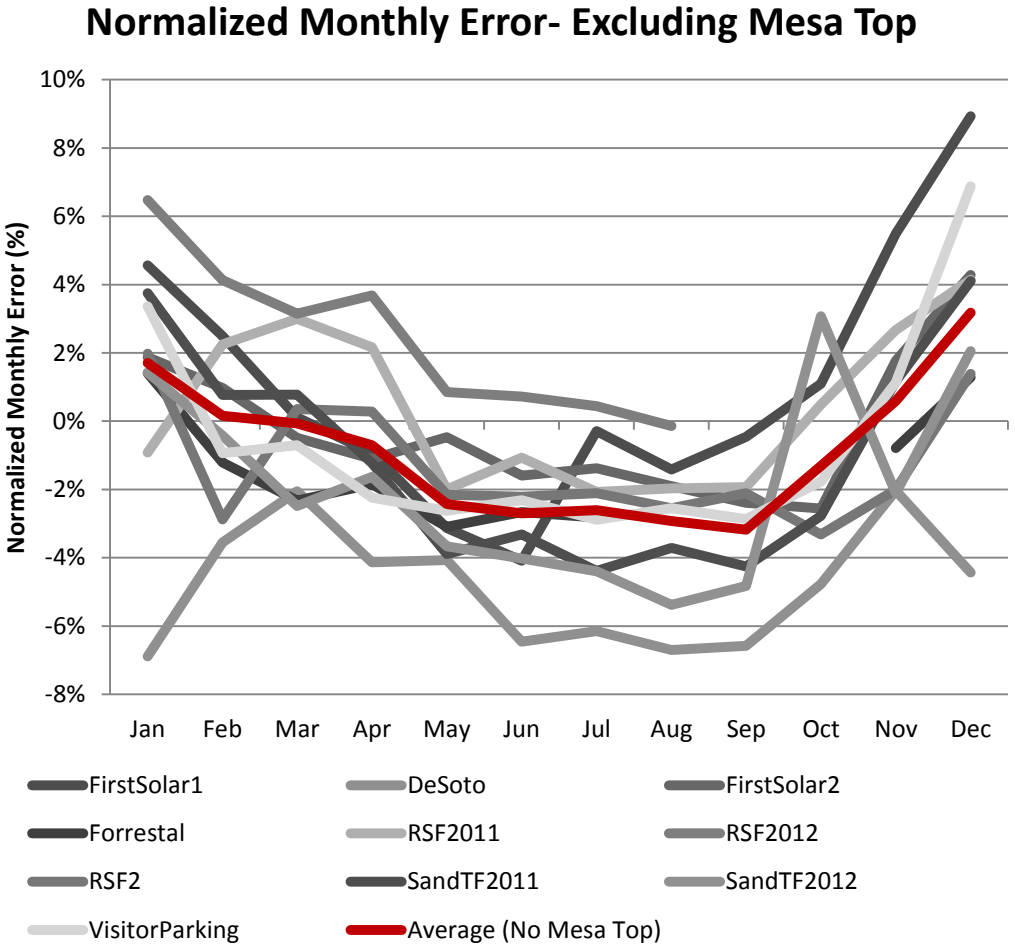


	S&TF	Forrest- al	RSF 1	RSF 2	Visitor Parking	Mesa Top	First Solar2	DeSoto	First Solar1
◆ 2011	-2.2%		-0.8%			15.5%	-0.5%		0.6%
■ 2012	-2.7%		1.8%	-1.4%	-1.2%	11.5%			
▲ Other Year		-2.1%						-4.8%	
● Average	-2.5%	-2.1%	0.5%	-1.4%	-1.2%	13.5%	-0.5%	-4.8%	0.6%

✖ Mesa Top system error decreases to 7.6% average with 2013.9.20 version, using suspected incorrect specifications.
DeSoto system error decreases to -4.3% with 2013.9.20 version.

Hours experiencing snow cover excluded

Seasonal Variation in Error



Hours experiencing snow cover excluded

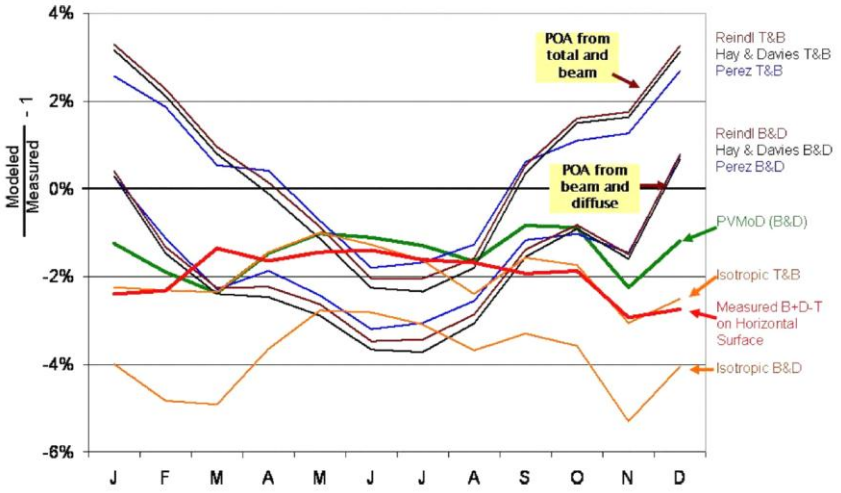
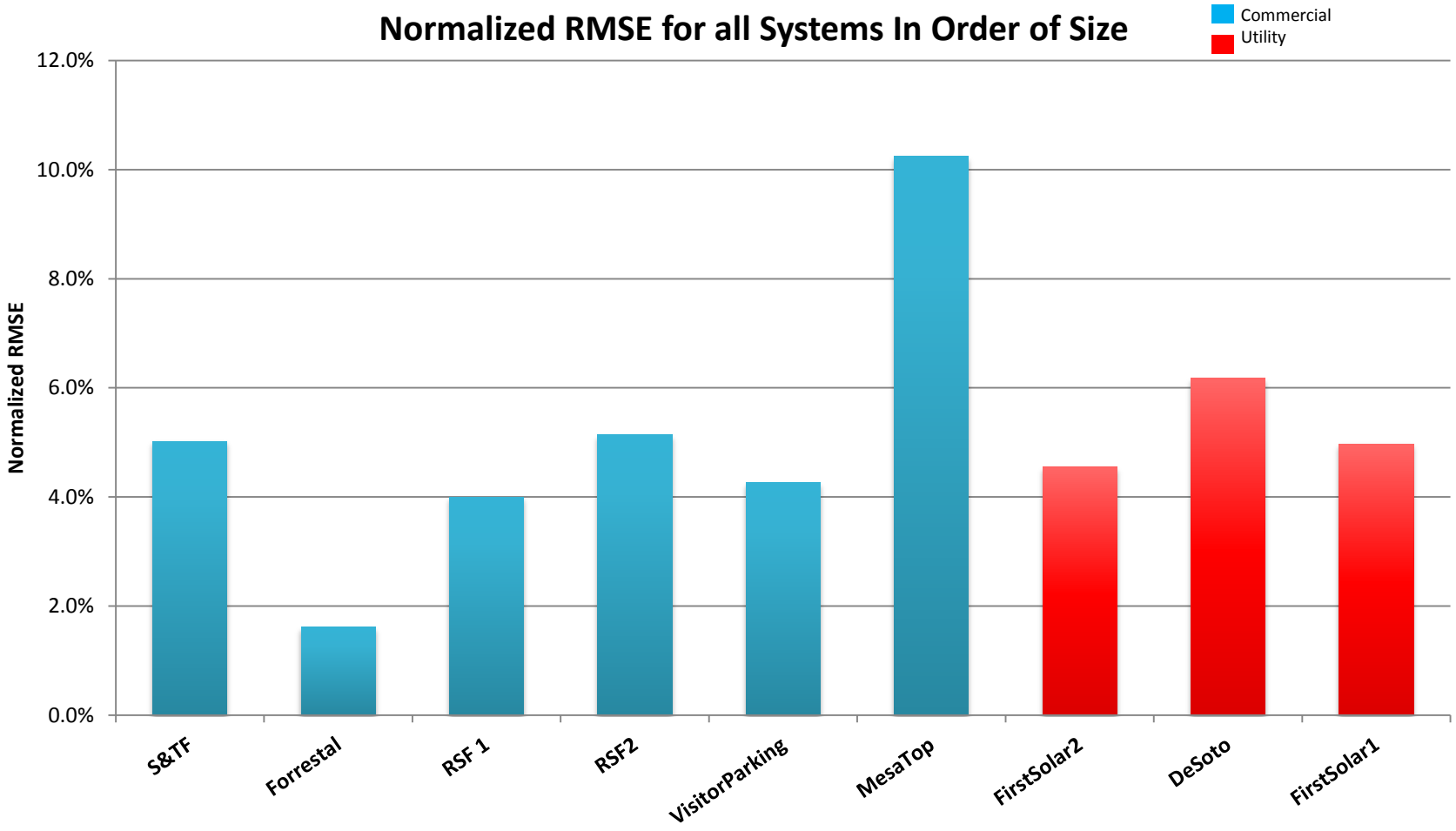


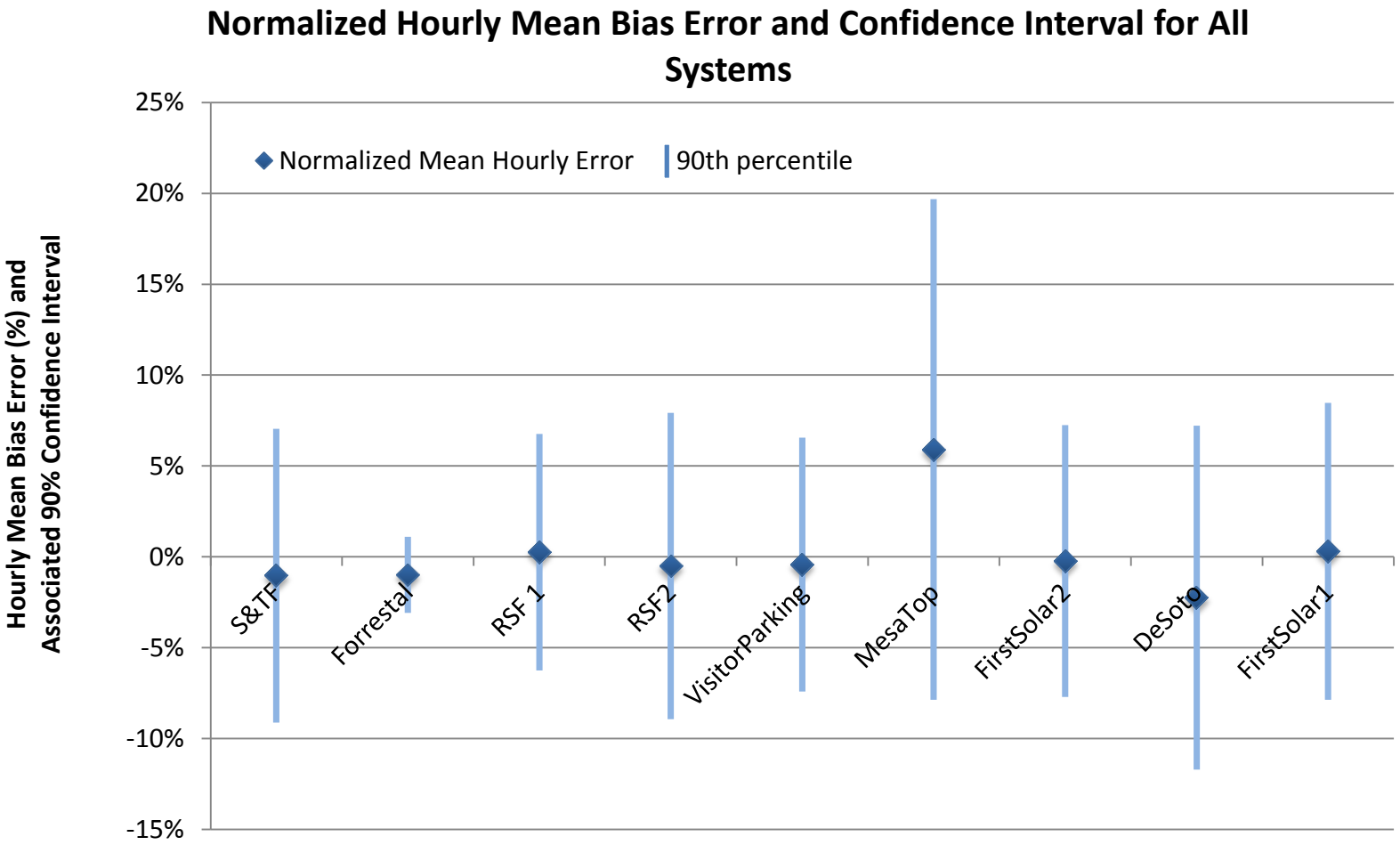
Image used with permission from Sandia National Laboratories [Cameron et al, "Comparison of PV System Performance Model Predictions with Measured PV System Performance", IEEE, 2008]

Normalized Root Mean Square Error



Hours experiencing snow cover excluded, Mesa Top and DeSoto still contain resolved backtracking error

Hourly Mean Error and Confidence Intervals



Hours experiencing snow cover excluded, Mesa Top and DeSoto still contain resolved backtracking error

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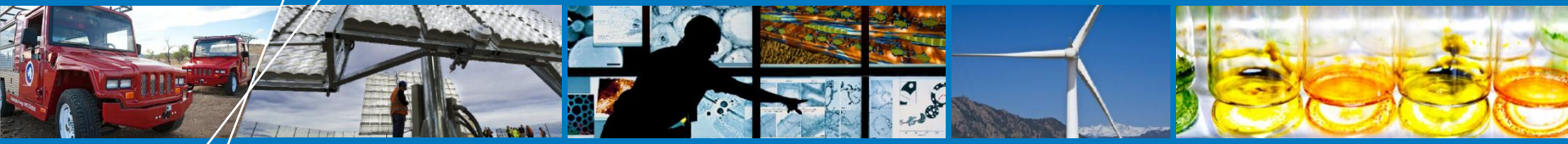

Conclusions and Future Work

Conclusions

FOR THIS VALIDATION STUDY

- **Annual agreement* within ± 3%**
- **Hourly agreement*:**
  - RMSE within 5.1%
  - MBE within ± 1.0%
- **Seasonal variation in monthly error**
  - Likely a result of this trend in transposition models
- **No increase in error with increase in system size**

*Mesa Top and DeSoto excluded from these results

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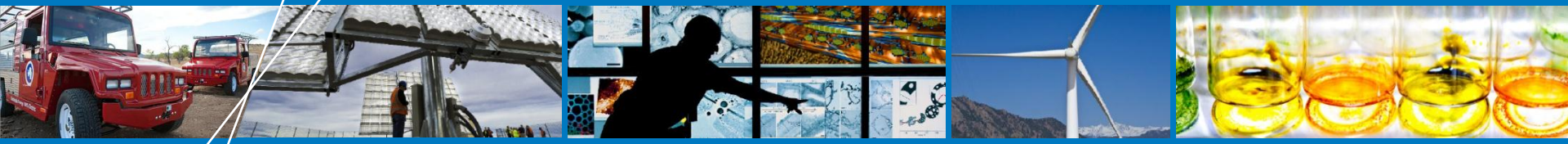

Questions?

Download the full report:

http://www.nrel.gov/docs/fy14osti/60204.pdf

Also found on the SAM Resources -> Case Studies and Validation page

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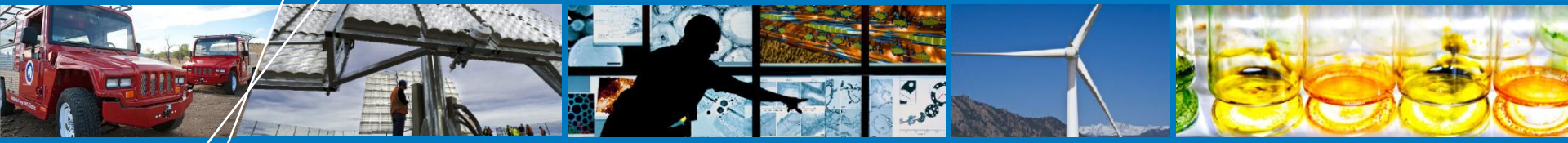

Appendix Slides

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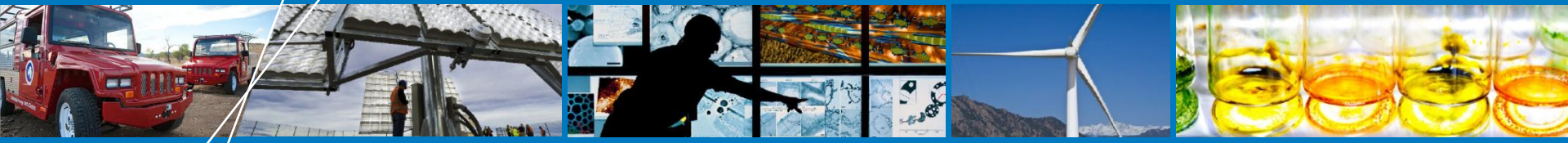
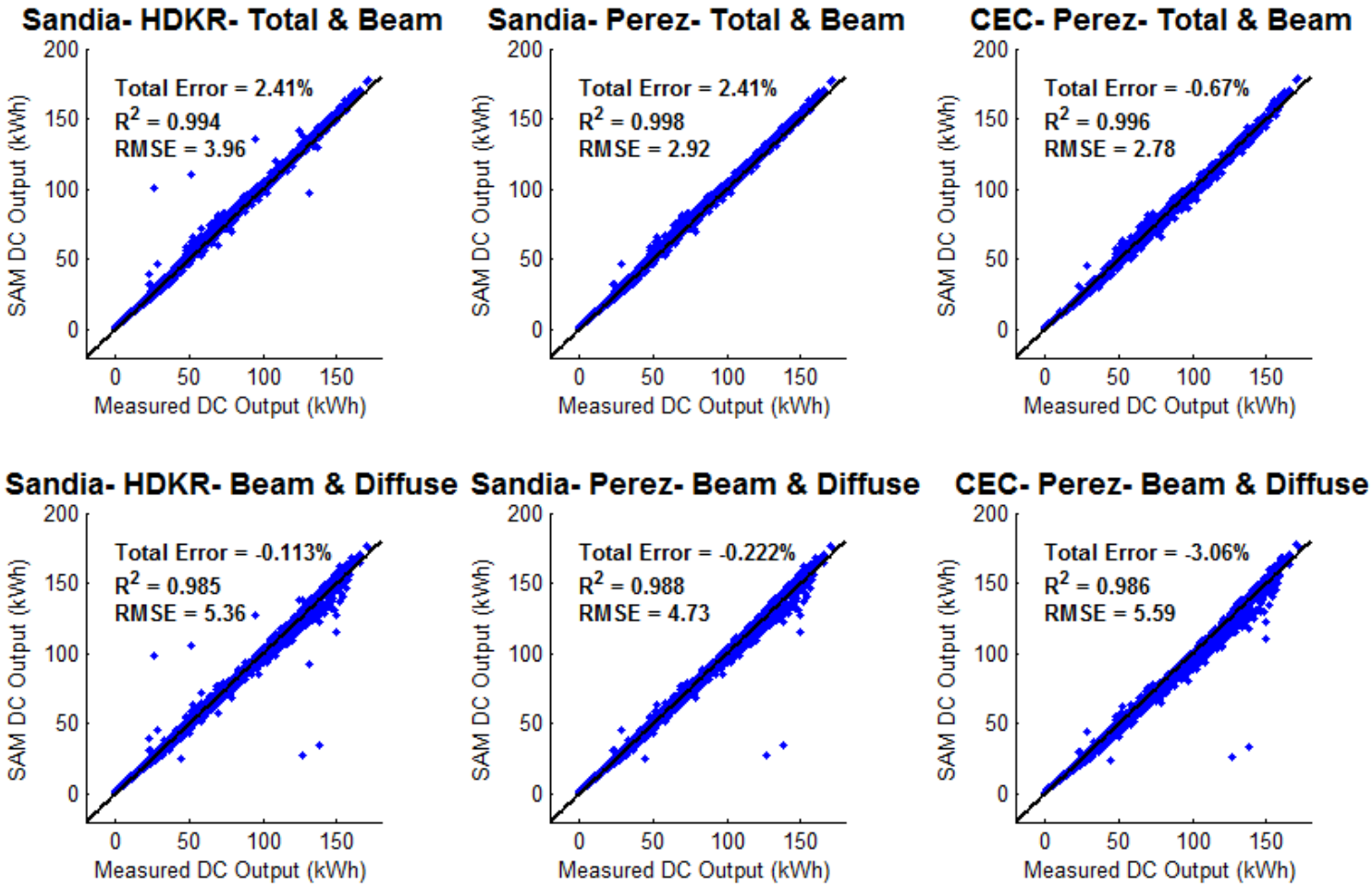


Model Option Comparisons

All Model Options Perform Similarly

System Advisor Model



Forrestal System (Washington D.C.)

Hours experiencing snow cover and shading excluded